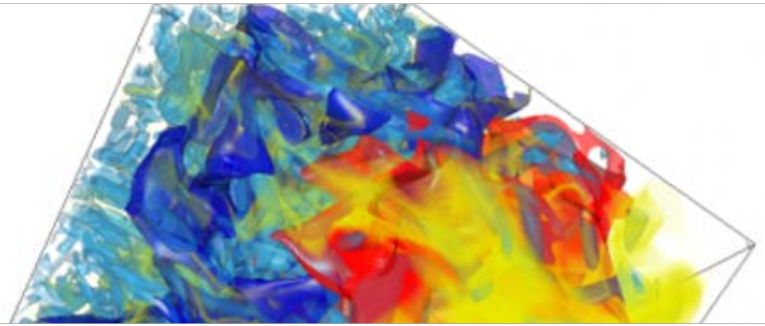

12-13th September

UKCTRF Annual Meet 2018

Flame dynamics within low emissions swirl-stabilized gas turbine combustion

Khawar Syed

Acknowledgements:

- GE
- Many former colleagues in GE, in particular, Fernando Biagioli, Stefan Wysocki , Bruno Schuermans and Thierry Lachaux
- Partners organizations, in particular, DLR and TU Munich

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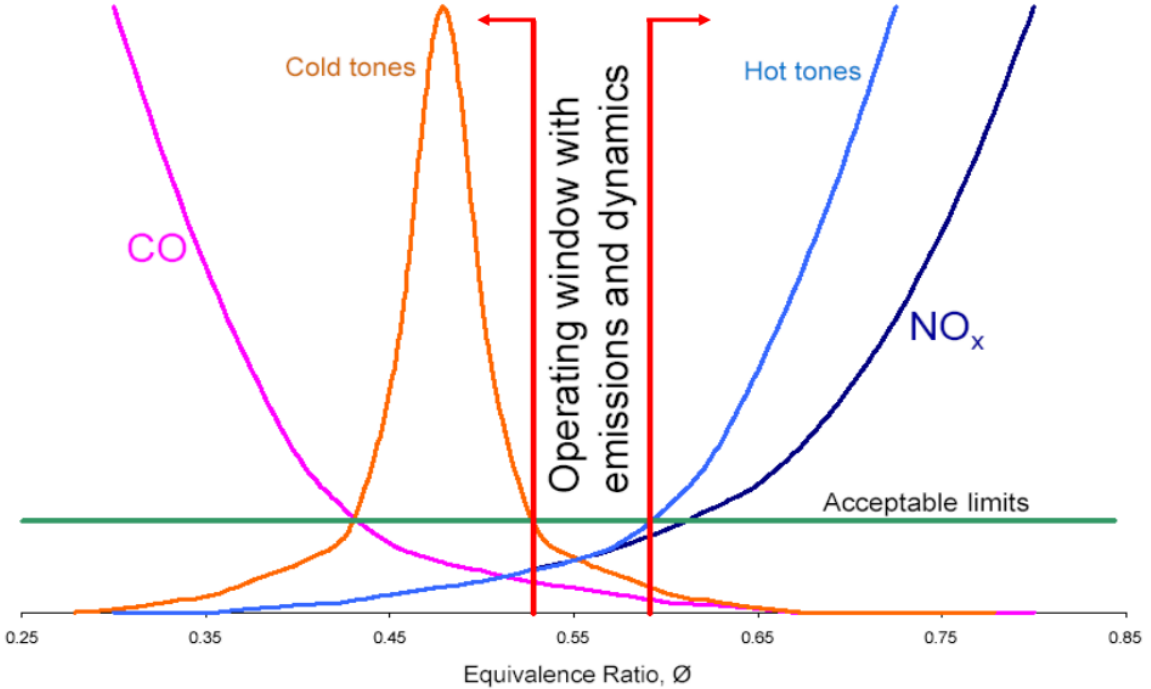
Agenda

- State-of-the-art gas turbine combustion
- Practical methods for dynamics control
- Flame response of swirl-stabilized flames
- Summary

GT operating window

Operating window narrows, as

- Efficiency increases
- Turndown demand increases
- Emissions targets reduce
- Component life increases
- Cyclic operation increases

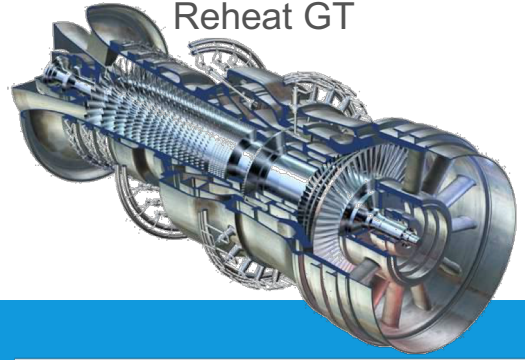


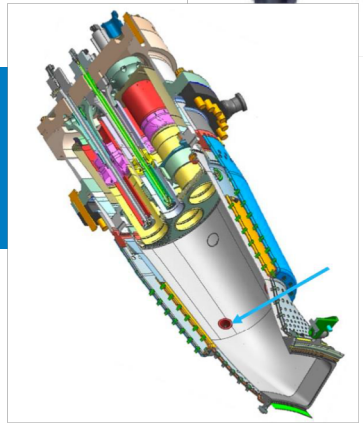
The Operating window will continue to decrease

Axially-staged combustion systems

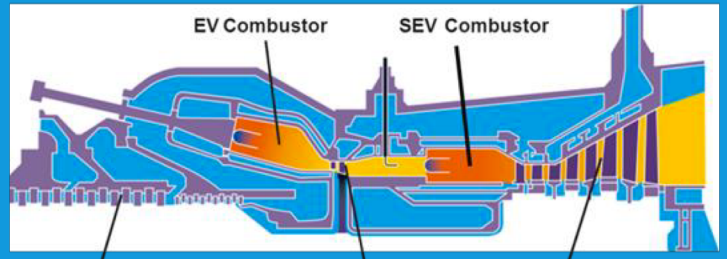
Standard GT

Reheat GT





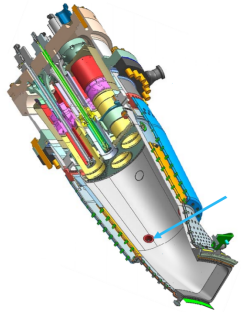
Axial Fuel staging



Sequential combustion

Combustion sustained by high upstream temperatures

Axial Fuel Staging and Sequential



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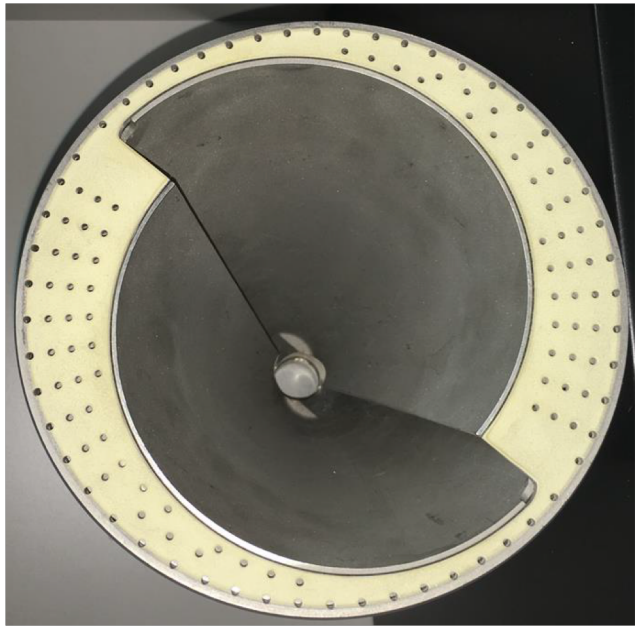
Examples of 1st stage burners

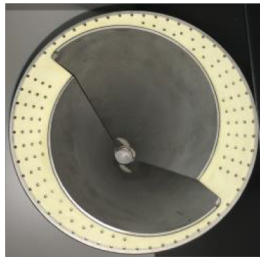
Free-standing Vortex Breakdown
EV Burner

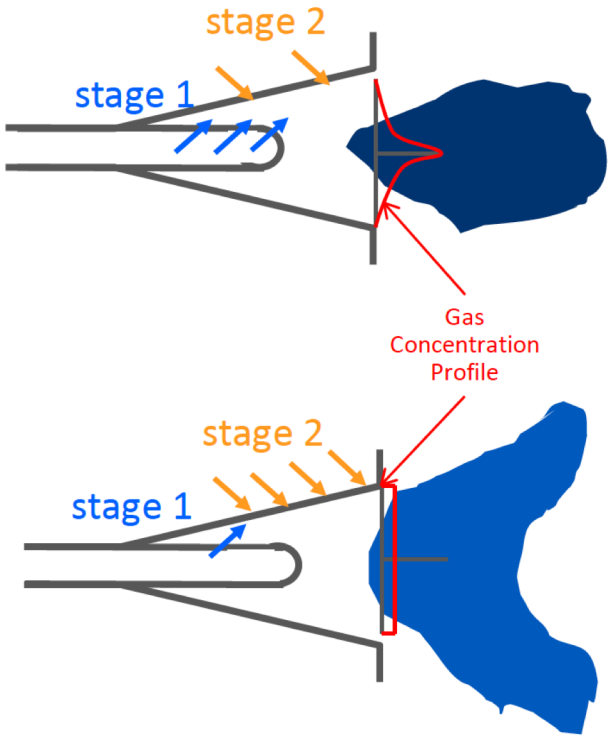


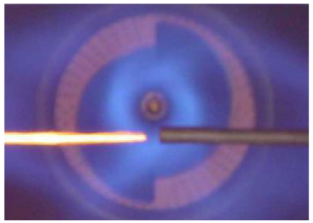
Anchored Vortex Breakdown
Swozzle

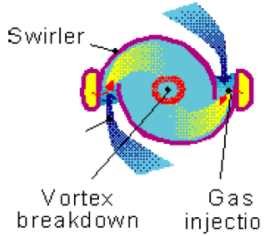
Fluid mechanics designed for flame stabilization

Lean premixed burner technologies: free-standing vortex breakdown









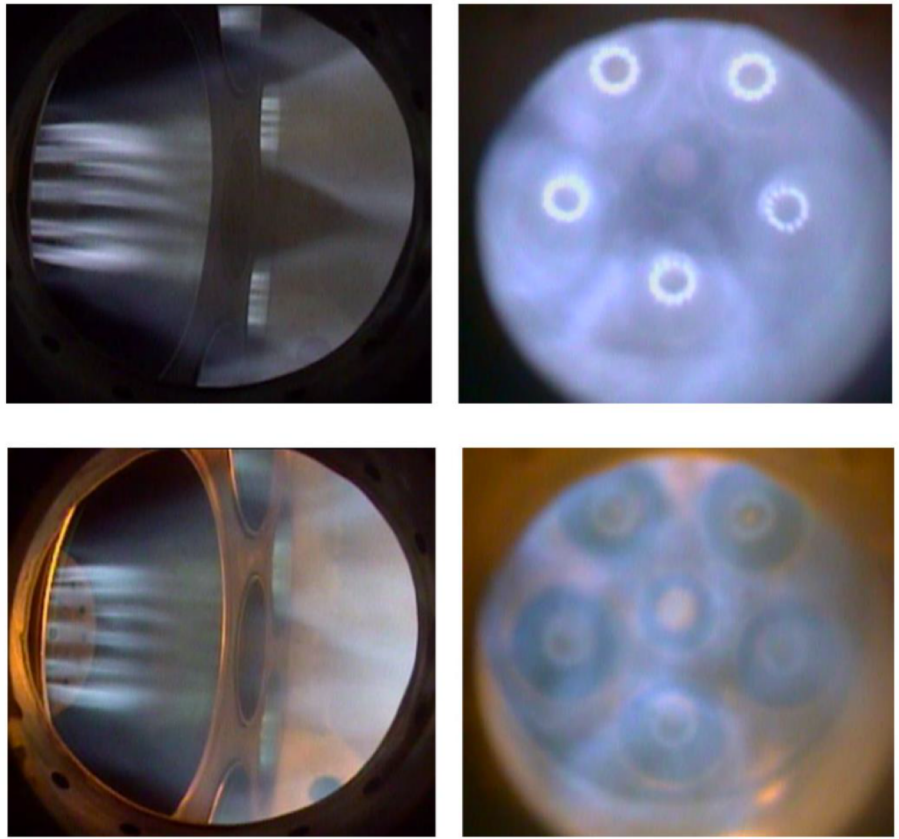
Rich Premix Mode

- Start-up with high fuel concentration on axis
- Good stability at low load

Lean Premix Mode

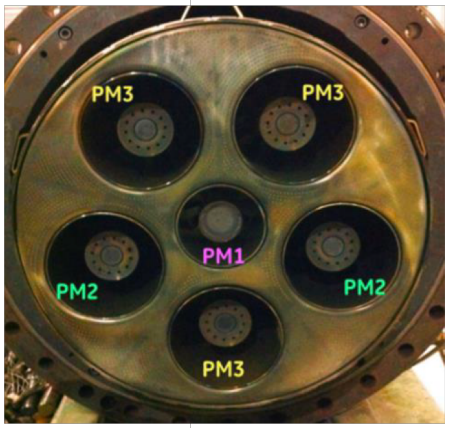
- fuel is evenly distributed
- Low NOx emissions at high load

Lean premixed burner technologies: anchored vortex breakdown



Rich Premix Mode

- Good stability at low load

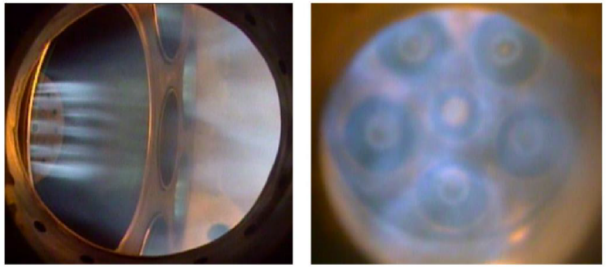


Lean Premix Mode

- fuel is evenly distributed
- Low NOx emissions at high load

Control of combustion dynamics

Fuel inhomogeneity



Variable fuel staging
- Burner staging
- Main/pilot fuel split variation

Drawback
- Cost of fuel stages
- Impact on NOx

Damping

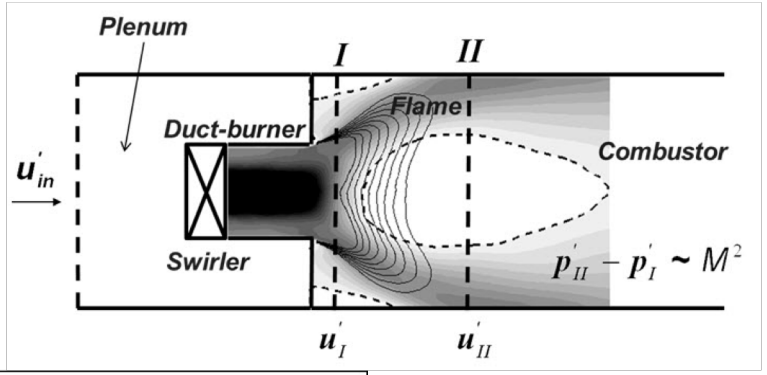
Low Frequency dampers
- Large volume
- Fairly easy to define mode shape

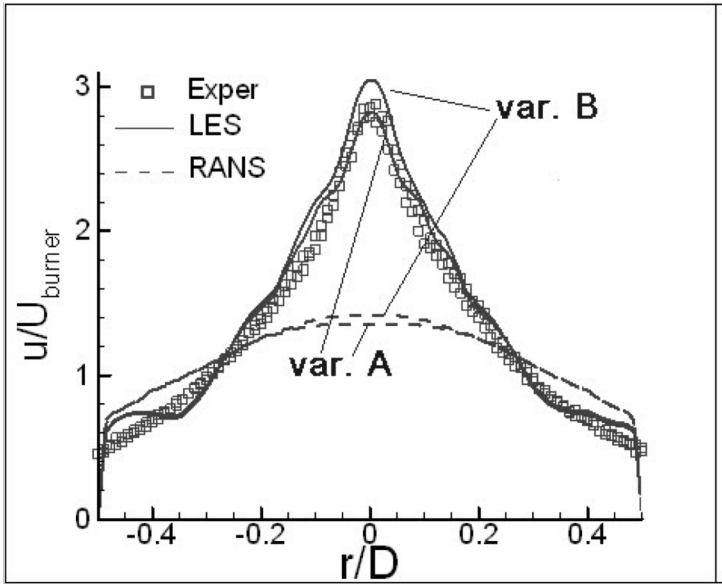
High frequency dampers
- Small volume
- Difficult to define mode shape

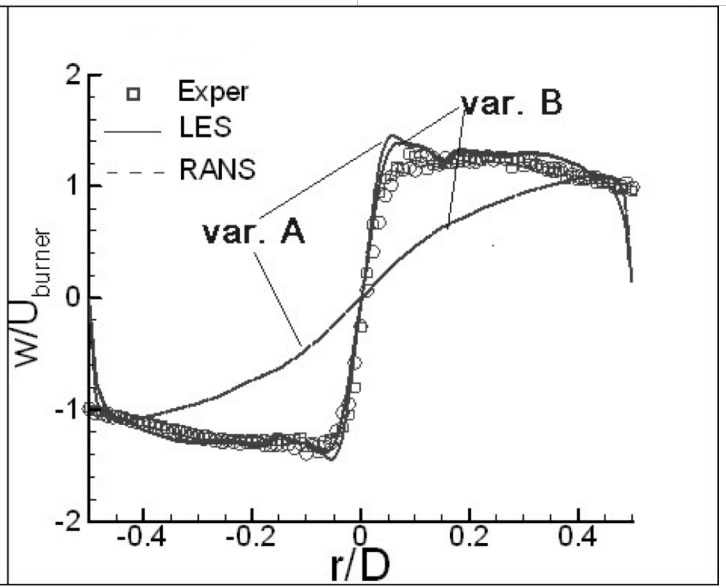
Drawback
- Cost
- Some impact on NOx

Prediction of combustion dynamics is a critical challenge

Swirl Burner aerodynamics

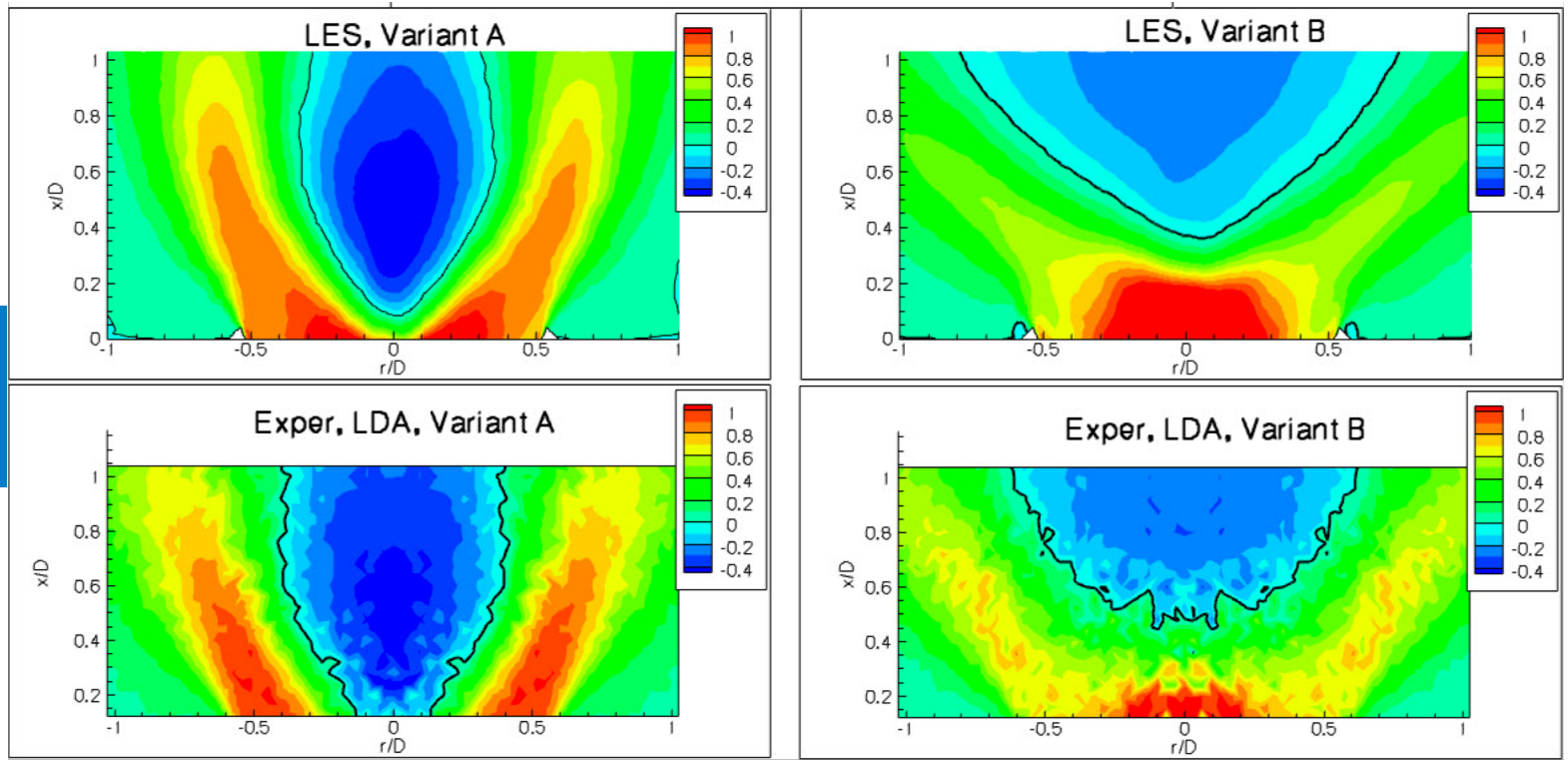






Water flow rig

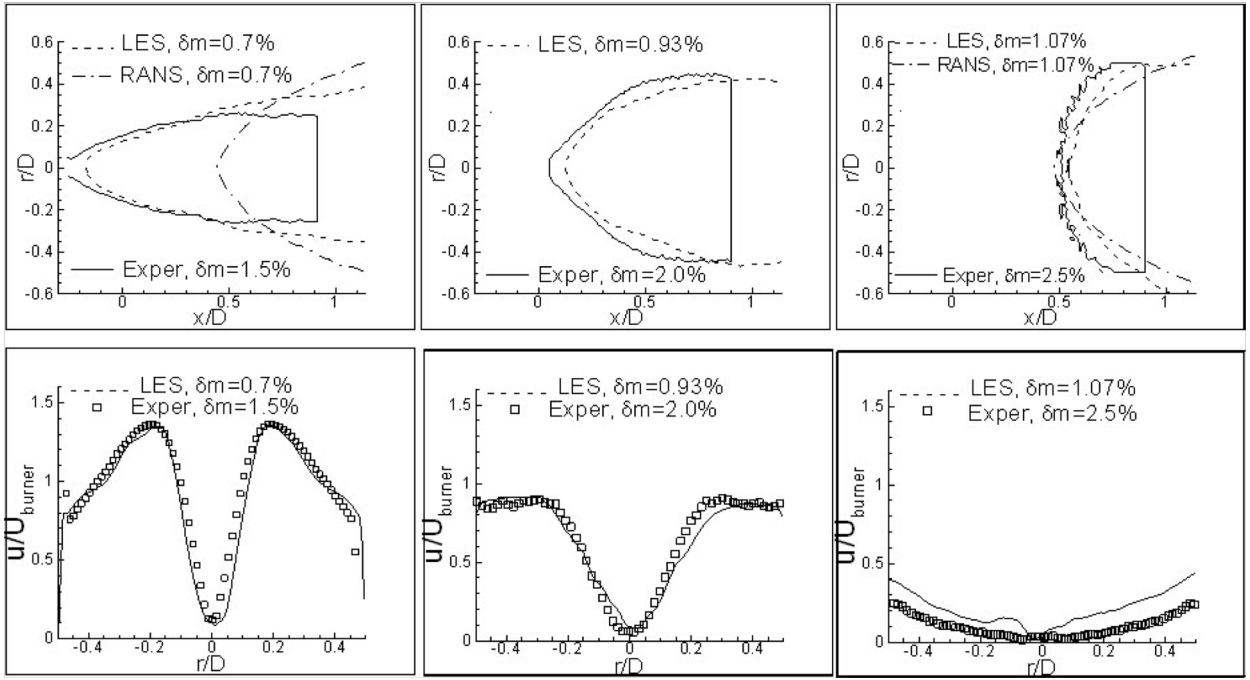
Swirl Burner aerodynamics



Water flow rig

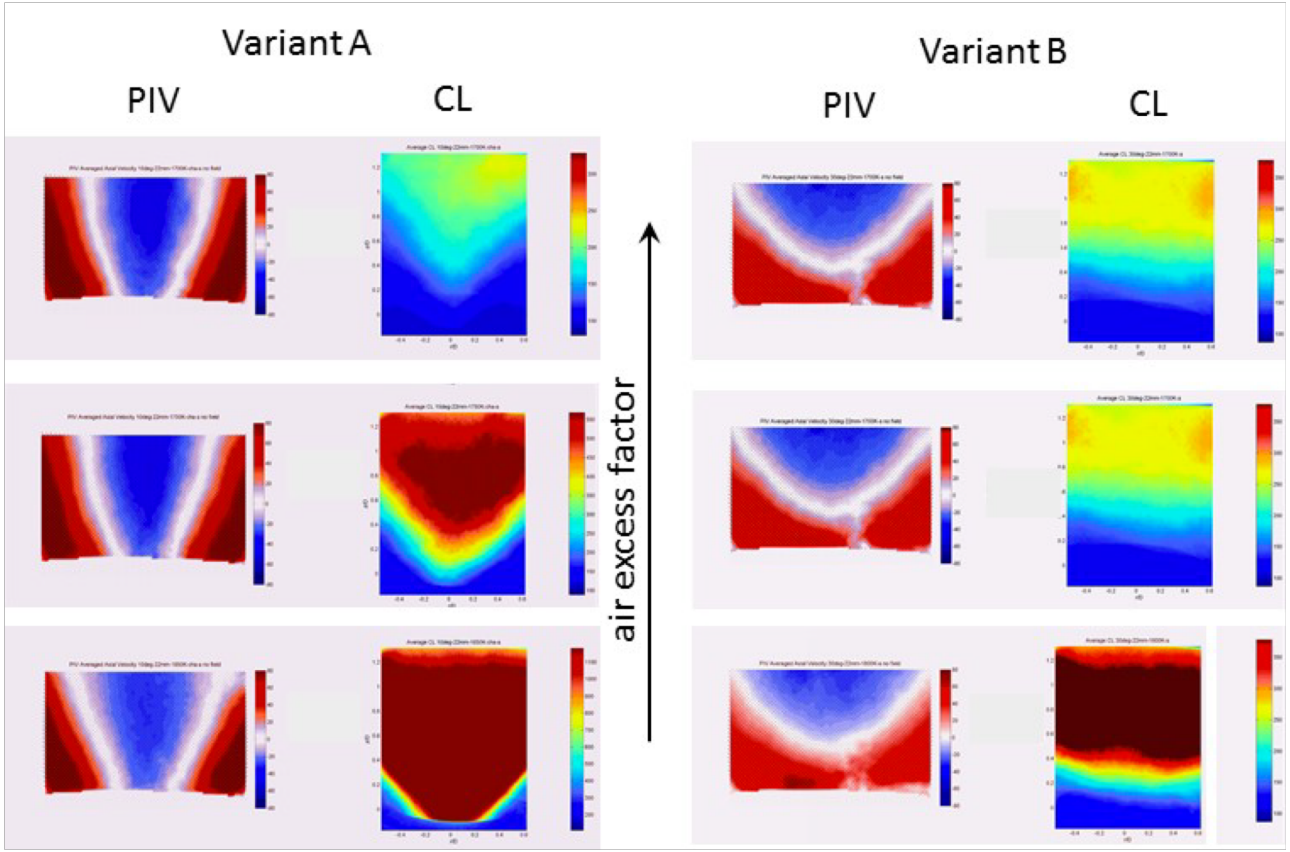
Minor change in BC has a major impact

Burner aerodynamics – impact of head air



Head air tailored to match experiment

Atmospheric combustion tests



Measurements by DLR

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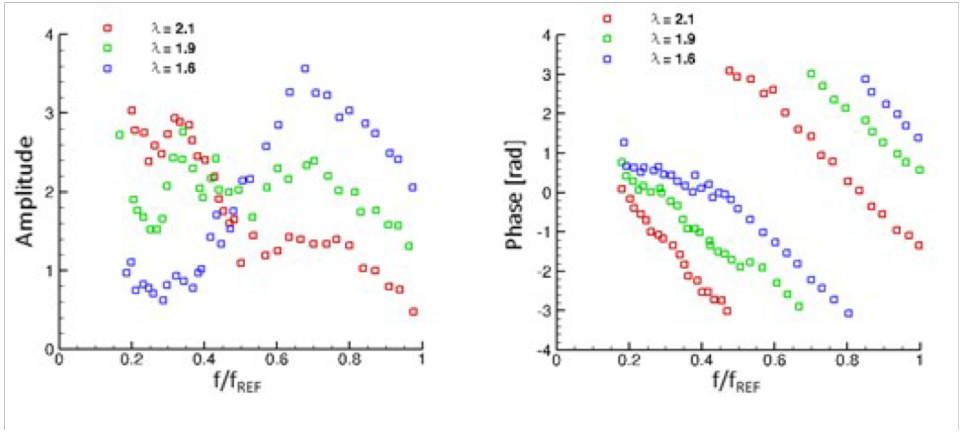
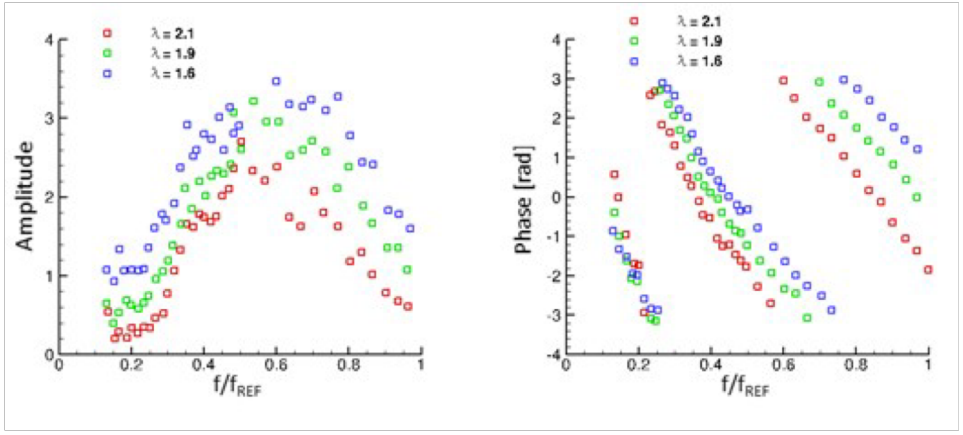
FTF from atmospheric combustion tests

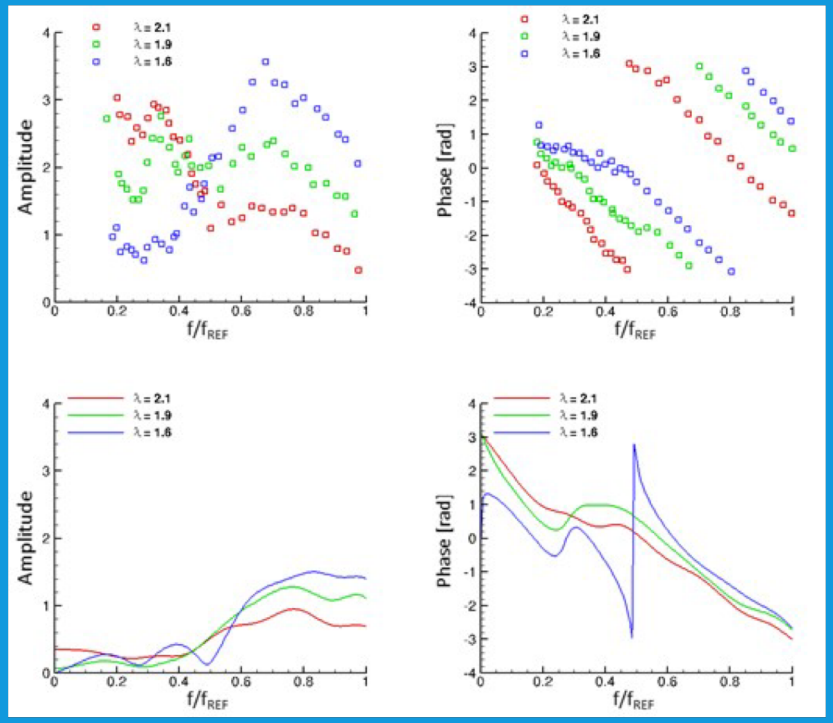


Variant A

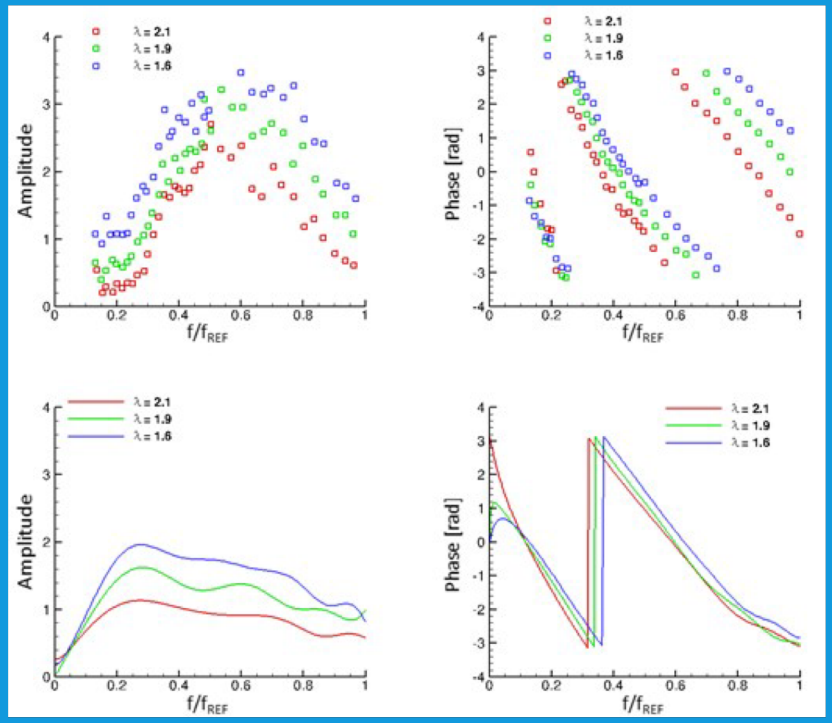


Variant B

FTF : Comparison between LES and experiment



Variant A



Variant B

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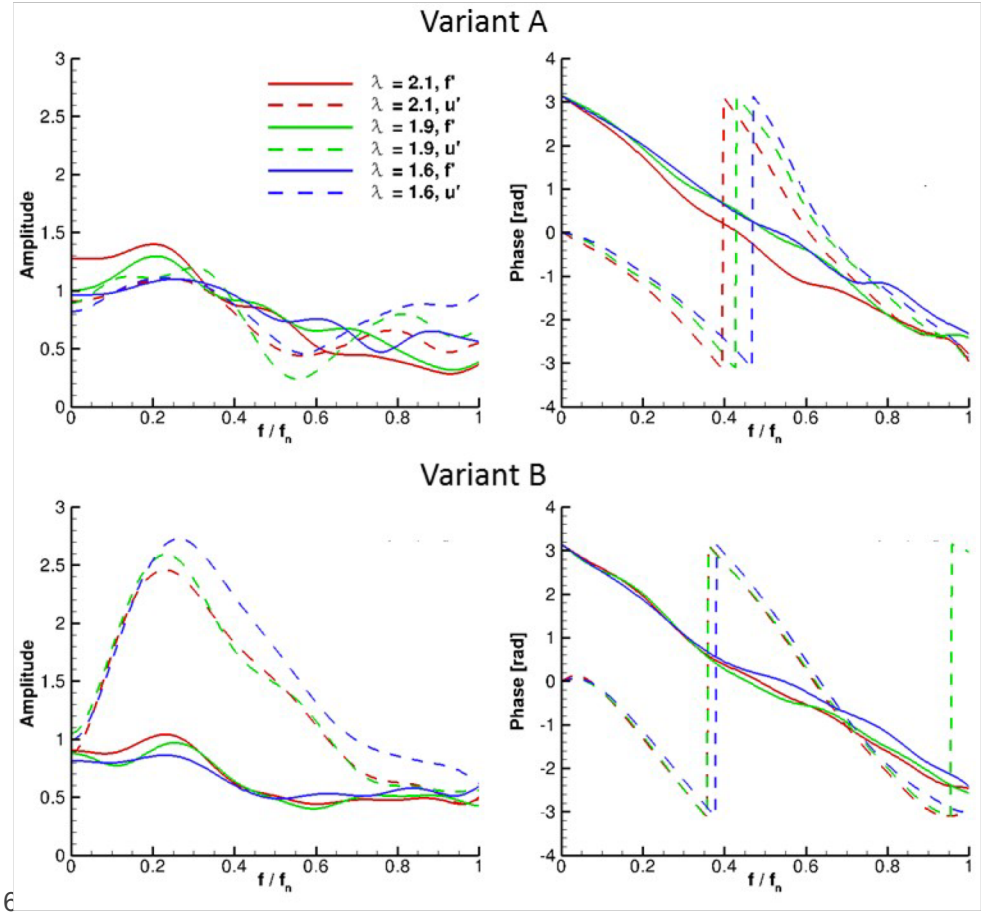
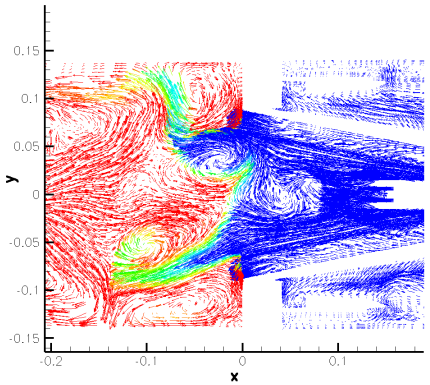
FTF : LES – split into contributions from f and u contributions



Summary

- Axial staged systems expand capabilities
- Control and mitigation of dynamics costs entitlement
- Vortex breakdown is highly dependent upon upstream flow
- Incompressible analysis sheds light on combustion dynamics
- LES is essential to reasonably represent the flow field
- Combination of numerics and experiments is essential



Thankyou

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